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Potentials and status of biogas as energy source in the Republic of Serbia

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ABSTRACT

Biogas is a sustainable and renewable energy source that can provide green energy, a better environment and new jobs. The aim of this paper is to present potentials for biogas production in the Republic of Serbia from different sources (agricultural crops directly provided for energy, livestock residues, municipal solid waste, slaughterhouse waste and wastewater from milk processing industry) and to analyze the current situation in this sector in Serbia. The barriers that limit the wider production of biogas are considered. Results have shown that there is a great potential for biogas production in Serbia. The yearly potentials were calculated as follows: biogas production potential from agricultural crops directly cultivated for energy is 0.85 Mega tons of oil equivalent (Mtoe); potential from livestock residues amounts to 94.13 ktoe; potential from municipal solid waste (MSW) is 49.72 ktoe; potential from slaughterhouse waste is 9.94 ktoe and potential from milk processing industry is 3.21 ktoe. The analysis of incentives, barriers and status of biogas technologies presented in this paper represents a contribution for the further improvement and analysis of the biogas sector in the Republic of Serbia.

Contents

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1. Introduction

Energy sector has an important economic role as the largest economic sector in the Republic of Serbia and contributes to more than 10% to Gross Domestic Product (GDP). Total consumption of primary energy in Serbia was 16.19 Mtoe in 2011 [1] out of which domestic production accounted for 62% and imports for 38%. Domestic production of primary energy includes exploitation and use of domestic resources of coal, crude oil, natural gas and renewable energy sources (hydro-potential, fuel wood, pellets, briquettes, geothermal energy, etc.).

Climate change, mainly caused by increased greenhouse emissions and reduction of fossil fuel reserves, initiated a number of measures on the global level. One of them is the increased use of renewable energy sources (RESs). The European Union Directive 2009/28/EC [2] defines detailed objectives in that area. The Republic of Serbia, as a candidate for membership in EU, is obliged to follow policy of the European Union and to implement concrete measures to support production and the use of renewable energy for the production of "green" energy.

Two priorities regarding the renewable energy sources exist in the Republic of Serbia [3]:

1. Establishing a long-term stable and supportive regulatory framework for RES.
2. Development and construction of new energy infrastructure facilities (power, thermo-power plants and energy networks) for RES.

Biogas is a renewable energy source that is generated from biomass under anaerobic conditions. Common sources for biogas production are agricultural crops, livestock residues, municipal solid waste, and organic waste and wastewater from different sectors. Biogas contains a high percentage of methane (50–75%) and biogas technology has great potential to reduce methane emissions to the environment. Serbia has relatively good conditions for biogas production, especially in agricultural sector, ensuring that this production does not influence the price of food on the market. The official register of biogas production potentials from different materials and industries does not exist in Serbia. Also, there is no adequate estimation of the potential for biogas production from agricultural land that is directly used for production of energy, taking into account the impacts on food prices and the loss of biodiversity. The Republic of Serbia also does not have reliable estimation on potential for biogas production from waste streams (municipal solid waste and waste streams from industrial systems-meat industry and milk industry), which contain significant amounts of organic matter that can be used as a substrate for biogas production. The review of biogas production potentials in this work represents a contribution to the analysis of the possibility of biogas production from different sources in Serbia. Through an integrated approach in analyzing the potential for biogas production from the most important resources, as well as by analyzing of existing economic and administrative barriers for use of biogas, it is intended to lay the groundwork that would serve to identify the real economic and sustainable potentials of production and application of biogas in the Republic of Serbia.

By signing the Treaty establishing the Energy Community of Southeast Europe and EU, Serbia has accepted the obligation to apply all the directives related to the renewable energy sources. Also, Serbia has accepted the obligation to increase the share of renewable energy sources in gross final energy consumption from 21.1% in 2009 to 27% in 2020. The share of electricity produced from hydro potential in the gross final energy consumption amounted to 9.6% in 2009, while the share of heat produced from biomass in gross final energy consumption amounted to 11.5%. Expected gross final energy consumption in 2020 is 10,330 ktoe [4]. In order to reach the mentioned target, the Republic of Serbia has prepared National Renewable Energy Action Plan (NREAP) up to 2020 [4]. According to the NREAP, the Republic of Serbia would produce 30 MW of energy from biogas plants till 2020. Biogas can be an important energy source in Serbia and contribute to the improvement of the energy sector, environment protection, job creation and rural development.

The aim of this paper is to present potentials for biogas production in the Republic of Serbia from different sources: agricultural crops directly provided for energy, livestock residues, municipal solid waste, slaughterhouse waste and wastewater from milk processing industry and to analyze the current situation in this sector considering the current barriers which limit the wider use of energy obtained from biogas in the country.

2. Review of different sources for biogas production in Serbia

Appropriate raw material for production of biogas must contain organic material that is suitable for anaerobic digestion. Such raw materials are agricultural biomass residues, livestock residues, municipal solid waste, animal waste and wastewater from food industry. Biogas production from different materials must be sustainable and should include energy, environmental and economic considerations. In the following sections, the review of different raw materials for the production of biogas and their availability in Serbia are discussed.

2.1. Agricultural crops

Agriculture is an important sector of the Serbian economy accounting to about 20% of the total employment and 8.3% of GDP. From 7.8 million ha of the total land area of Serbia, the area devoted to agriculture constitutes 5.1 million ha out of which 1.55 million ha are grassland, 3.35 million ha are cultivated. Every year over 0.2 million ha are left fallow [4].

Production of major crops in Serbia for the period 2007–2011 is shown in Fig. 1.

The largest part of crop residues comes from corn and wheat. These two cultures are dominant species in the field of crops. The amount of crop resides is about 12 million t/year. It is estimated that one-third of the total crop residues can be used for energy purposes. Application of biomass for energy production in the Republic of Serbia has already been investigated [5–9]. According to the Serbian Action plan for biomass for the period 2010–2012, potential in agricultural sector for energy production is over 1 Mtoe: crop residues 1.023 Mtoe and liquid manure for biogas

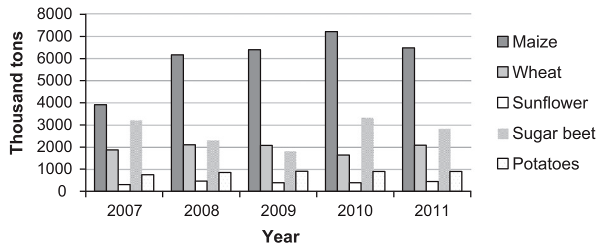

Fig. 1. Production of major crops in Serbia in the period 2007–2011 (in thousands tons) [10].

Table 1
Number of livestock (in thousands) in the Republic of Serbia in the period 2007–2011 [10].

	2007	2008	2009	2010	2011
Cattle	1087	1057	1002	938	937
Pigs	3832	3594	3631	3489	3287
Sheep	1606	1605	1504	1475	1460
Poultry	16,422	17,188	22,821	20,156	19,103

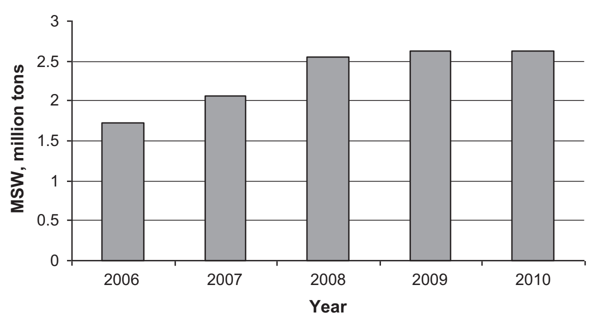

Fig. 2. Generation of MSW in Serbia in the period 2006–2010.

production 42.240 ktoe (only manure from medium and large farms in Serbia is considered).

2.2. Livestock residues

Livestock residues are excellent material for the production of biogas. According to the current farming practice in Serbia, the farmers collect the manure in lagoons or large tanks. Manure of sheep and goats is difficult to collect because of farming practices. Intensive livestock in Serbia covers cattle, pigs and poultry farming. Nine biogas plants were constructed on large pig and cow farms in Serbia 25 years ago. Today, these plants are not in operation.

Animal manure has high water content, and it can be digested anaerobically for the production of biogas. Number of livestock according to official statistic [10] is presented in Table 1.

2.3. Municipal solid waste

Municipal solid waste (MSW) is waste collected by local municipalities. The main part of municipal solid waste comes from households, but waste from commerce and trade, offices and institutions are also included in municipal solid waste.

Amount and composition of MSW depends on the stage of economic development of the country, living standard and consumer's habits. The indicator used for municipal waste generation quantification is the waste per person generation, expressed in kg/person/year. This indicator for Serbia equals to 0.36 t/person/year [11]. The generation of MSW in Serbia in the period 2006–2010 is shown in Fig. 2 [11].

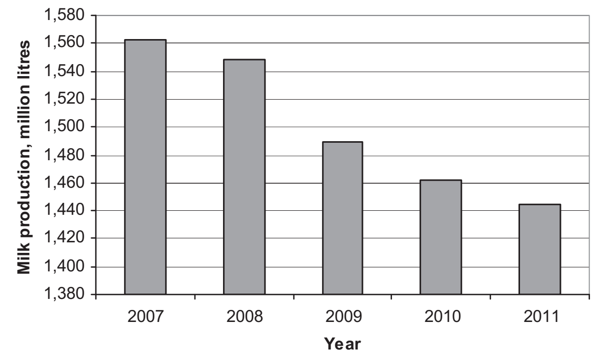

Fig. 3. Milk production in Serbia in the period 2007–2011 (in million litres).

Table 2
Estimated biogas yield for different feedstock.

Feedstock	Dry Matter (DM) content feedstock (%)	Estimated yield of feedstock (t_{DM}/ha)	Biogas yield (m^3/t_{DM})	Biogas yield ($m^3/t_{fresh\ material}$)	References
Corn silage		16	576		[21,22]
Municipal Solid Waste (MSW)	40		308		[22]
Slaughterhouse waste				260	[23]

The determination of waste composition is crucial for use of MSW as energy source. Organic fraction is dominant [12], with about 30% in waste composition of MSW, and that is good potential for production of biogas in the anaerobic digestion process. According to the EU legislation [2], energy produced from the biodegradable fraction of MSW is considered as renewable energy. According to the European Environment Agency (EEA) [13], 30–40% of municipal solid waste generated in Europe can be used for anaerobic digestion.

2.4. Slaughterhouse waste

This waste stream is generated in the industrial process such as slaughterhouses, meat processing plants, etc. Slaughterhouse waste is an ideal substrate for biogas production, because it contains high concentration of organic matter (proteins and lipids). Pitk et al. [14] investigated production of biogas from slaughterhouse waste. Yields of biomethane were between 390 and 978 $m^3_{CH_4}$/t volatile solids (VSs) in their investigation. Hejnfelt et al. [15] studied anaerobic digestion of slaughterhouse by-products. In that study, yields of biomethane were between 0.225 and 0.619 m^3/kg_{VS}.

The Republic of Serbia has 900 registered plants for slaughter and meat processing. According to statistical data [12] animal waste in Serbia includes 28,000 t/year of dead animals and 245,000 t/year of slaughterhouse waste. Legislation for biogas production from this type of waste was adopted in 2011 according to the EU legislation [16]. Biogas technology can be a good way in which the plants which generate these waste streams can solve the waste deposition problem and at the same time earn some extra income.

2.5. Wastewater from milk processing industry

Waste water streams from food industry are biodegradable with high concentrations of organic compounds and great values for biochemical or chemical oxygen demand (BOD, COD), so they present an ideal material for biogas production. The composition of wastewater from food industry is difficult to predict due to the

Table 3
Estimated biogas production of livestock manure per head (m^3/head/day) [24,25].

Livestock categories	Estimated Fresh manure (FM) (kg/head/day)	Dry matter (DM) (%FM)	Biogas producing rate (m^3/kg_{DM})
Cattle	28	16.7	0.22
Pigs	2.2	18.5	0.28
Poultry	0.1	30	0.32

differences in BOD and pH in effluents from different production processes and seasonal nature of food processing.

In food industries, the milk processing industry is the largest source of wastewater in many countries [17]. These wastewaters are highly biodegradable and can be treated by biological wastewater treatment systems for biogas production.

Milk production in the Republic of Serbia is one of the most important agricultural industries, which includes more than 280 thousand producers. It contributes significantly to the Serbian economy. It is a sector with an annual turnover of over 500 million Euros. Milk production decreased during the period 2007–2011 (Fig. 3) [10], because the number of cattle decreased during this period due to economic crisis. Milk is mainly produced on small family farms. 50% of the total milk production is conducted in large companies [18].

3. Calculation of biogas production potential from different sources

3.1. Methodology

3.1.1. Methodology for the calculation of biogas production potential from agricultural crops directly provided for energy

European Environment Agency (EEA) states that 5–10% of agricultural land can be used for energy production [19]. Also, the European Biomass Association (AEBIOM), that brings together 30 national associations and key European institutions in the field of biomass, shares the same opinion. According to their methodology for assessment of biogas production potentials in EU members, by using agricultural land directly for energy production, 5% of agricultural land can be used for this purpose [20] without significant repercussions on food prices and the biodiversity. In this work we rely on these recommendations in order to calculate the biogas production potential from agricultural crops directly provided for energy. Using the conservative assumption of 5% the available agricultural land for the production of energy could be 175,000 ha. Since every year in Serbia more than 200,000 ha of agricultural land remains uncultivated, it could be used for biomass production.

It was assumed that the corn silage from this area of arable land would be used for biogas energy. Serbia has 3.55 million ha arable land for agricultural purposes. Becker et al. [21] and Pöschl et al. [22] researched the production of biogas from corn silage in the process of anaerobic digestion (Table 2).

Based on estimations shown in Table 2 and recommendations of the European Biomass Association the potential for biogas production from agricultural crops directly provided for energy in Serbia was determined. The amount of biogas production potential was determined as

$$P = 0.05ABC \qquad (1)$$

where P is the Biogas potential (m^3/year); A the total arable land (ha); B the Yield of corn silage dry matter (DM) per ha and C the Biogas yield (m^3/t_{DM}).

Table 4
Characteristics of wastewaters from milk processing industry [29].

TS (mg/L)	TN (mg/L)	BOD (mg/L)	COD (mg/L)
250–2750	10–90	650–6250	400–15,200

3.1.2. Methodology for the calculation of biogas production potential from livestock manure

For determination of biogas production potential from livestock residues the estimations proposed by Lleleji [24] and Guo Guo [25] were used. 2011 year was used as a base for the number of livestock (Table 1) in calculation. It was taken that 35% of total manure from cattle and pigs would be available for biogas production [20]. In the case of poultry farming, it was estimated that 15% of total manure would be available for anaerobic digestion (only poultry on medium and large farms in Serbia was considered) [26]. Estimated data for calculation of biogas production from livestock residues in Serbia are presented in Table 3.

The amount of biogas production potential from livestock residues was determined as

$$P_1 = NA_2B_2C_2 \qquad (2)$$

where N is the number of livestock; P_1 the biogas potential (m^3/day); A_2 the estimated fresh manure per head (kg/head/day); B_2 the estimated percentage of dry matter (% DM) and C_2 the estimated biogas producing rate (m^3/kg_{DM}).

3.1.3. Methodology for the calculation of biogas production potential from MSW

Assessment of potential of biogas production from MSW [22] was based on data shown in Table 1. Population in Serbia was 7,186,862 in 2011 [10]. For calculation of biogas production potential from MSW it was assumed that 30% of municipal solid waste generated in Serbia would be used for anaerobic digestion [13]. Potential of biogas production from MSW in Serbia was obtained as

$$P_3 = 0.3A_3B_3C_3D \qquad (3)$$

where P_3 is the biogas potential (m^3/year); A_3 the population in Serbia in 2011; B_3 the waste generation per person per year; C_3 the estimated percentage of dry matter (DM) in MSW and D the biogas yield (m^3/t_{DM}).

3.1.4. Methodology for the calculation of biogas production potential from slaughterhouse waste

For obtaining the potential of biogas production from slaughterhouse [23] the data presented in Table 1 was used. It was assumed that 30% of total generated slaughterhouse waste would be used for biogas production. Potential for biogas production from slaughterhouse waste in Serbia is given as

$$P_4 = 0.3A_4B_4 \qquad (4)$$

where P_4 is the biogas potential (m^3/year); A_4 the total slaughterhouse waste in Serbia (t/year) and B_4 the biogas yield ($m^3/t_{\text{fresh material}}$).

3.1.5. Methodology for the calculation of biogas production potential in milk processing industry

Milk production in Serbia amounted to 1.445 million l in 2011. It was estimated that 722,500 m^3 of milk production was conducted in large companies in 2011 [18]. This was used as a base for the calculation of the biogas production potential in milk processing industry.

The amount of wastewater generated in milk processing industry is about 0.8–1.7 (l_{water})/($l_{\text{received milk}}$) according to EU BAT for Food, Drink and Milk Industries [27]. It is estimated that this value is higher

Table 5
Potentials of biogas production from different feedstock, calculated based on the methodology given in this paper.

Feedstock	Biogas potential (million m^3/year)
Agricultural crops directly provided for energy	1635.8
Municipal Solid Waste (MSW)	95.6
Livestock residues	
Cattle manure	123.1
Pigs manure	47.8
Poultry manure	10.0
Slaughterhouse Waste	19.1
Milk processing industry	6.2

in Serbia due to the inefficiency in water management. For the calculations in this work the estimated value of wastewater generation used was 3 $(l_{wastewater})/(l_{processed\ milk})$. IPCC Guidelines [28] recommended the range of wastewater generation in milk processing industry between 3 and 10 $m^3/t_{milk\ product}$. Typical pollution loads (total solids (TS), total nitrogen (TN), biochemical and chemical oxygen demand (BOD and COD)) and concentrations released with the wastewater from the milk processing industry are indicated in Table 4 [29].

The estimated value of COD used in our calculations was 5 kg/m^3 [29]. The methane production in anaerobic treatment of milk processing industry wastewater could be estimated as 0.35 $Nm^3_{CH_4}/kg_{COD}$ removed [30]. The caloric value of CH_4 used was 35.9 MJ/Nm^3 and estimated caloric value of biogas used was 22 MJ/Nm^3.

Potential of biogas production in milk processing industry was determined as

$$P_5 = A_5 B_5 C_5 D_2 E/F \tag{5}$$

where P_5 is the biogas potential (m^3/year); A_5 the amount of processing milk in 2011 (m^3); B_5 the estimated value for generated wastewater per m^3 of processing milk $((m^3{}_{generated\ wastewater})/(m^3{}_{processing\ milk}))$; C_5 the estimated value of COD (kg/m^3); D_2 the methane production per kg COD removed ($Nm^3_{CH_4}/kg_{COD\ removed}$); E the calorific value of CH_4 (MJ/Nm^3) and F the calorific value of biogas (MJ/Nm^3).

3.2. Results

The results of the calculation of biogas production potentials from different raw materials according to the methodology discussed in a previous section are given in Table 5.

Biogas production potential from agricultural crops directly provided for energy was calculated to be 1635.84 million m^3/year (Table 5). The calorific value of biogas (60% methane) used was 0.52 toe/1000 m^3 biogas [20]. According to that fact, potential for biogas production from agricultural crops directly provided for energy was 850.63 ktoe or 5.25% of primary energy consumption in Serbia in 2011. 0.2 million ha/year of arable land are left fallow [4] and that is a good opportunity for biogas production.

According to Table 5 the production of biogas from agricultural crops directly provided for energy represents the largest biogas production potential in Serbia. Bearing in mind that the consumption of natural gas in Serbia amounts to 2.5 billon m^3 of natural gas, obtained values represent a good potential of replacing the natural gas. But, according to Serbian National Renewable Energy Action Plan (NREAP) up to 2020 [4] 30 MW will be installed for production of electricity from biogas. Annual amount of corn silage per 1 ha provides work of biogas cogeneration power plants with power of 2.2 kW [31]. If we assume the share of produced electricity from biogas from corn silage until 2020 according to NREAP as 25%, 50%, 75% of total power respectively, it would mean that 3409 ha, 6818 ha and 10,227 ha respectively is needed for corn silage production. This is in the range from 2% to 6% of the estimated 175,000 ha (5% of the total cultivated land in Serbia). Besides the consumption of biogas for electricity production, it will be used for other purposes, increasing the total amount of agricultural land needed. But the fact remains, that only a fraction of biogas production potential is planned to be used by 2020. Despite the fact that predicted percentage of land utilization for crops used for biogas production is less than maximum available, the replacement of any amount of natural gas import would mean the reduction of trade deficit of the Republic of Serbia. In order for this potential to be efficiently used the long-term policy of biomass for biogas production should be adopted, bearing in mind not to compromise the food production and price on the domestic market.

Further, Table 5 shows that the potential for biogas production from livestock residues was calculated to be 180.9 million m^3 biogas per year or 94.13 ktoe/year. The potential for biogas production from cattle and pigs manure (using 35% of total cattle and pig manure) was calculated to be 170.9 million m^3 biogas or 88.91 ktoe. According to the methodology in Biogas Road Map for Europe [20] (5% land + 35% manure of cattle and pigs), the potential for biogas production was determined to be 0.94 Mtoe. The production of biogas from livestock manure should be combined with the use of agricultural crops because of the low content of the organic matter and large energy consumption for maintaining the temperature conditions of anaerobic digestion in these systems. In this kind of production process, the byproduct is the digestate which can be used as a fertilizer, diminishing the costs of the agricultural crops production.

It is expected that this potential will be mainly used on medium and large farms. For small farms due to the small land area and number of livestock, biogas projects are not economically feasible. In the case of small farms, it is necessary to work on the promotion of associations of small farmers, in order to use this potential.

Also, based on the applied methodology 771,181 t of MSW can be used for biogas production. Potential of biogas production from MSW in Serbia is estimated as 95.6 million m^3 biogas per year (Table 5) or 49.72 ktoe. According to this analysis MSW could be a significant energy source for the Republic of Serbia.

Speaking about the potentials of MSW in biogas production, it should be noted that primary goal is of the whole process is management and treatment of MSW. So, the potential of biogas production could be increased, but it is necessary to extend the system of waste collection especially in rural areas. Waste Management Strategy [12] foresees the construction of 26 regional landfills. By now, seven landfills have been built. This can be a good possibility for collection of biodegradable fraction of waste, which is a requirement for the production of biogas. Having in mind this trend of building landfills, as well as improvements in the waste management system, it is expected to achieve 10–20% of the certain amount of biogas production potential from MSW by 2030.

As it can be seen from Table 5, 73,500 t of slaughterhouse waste can be treated for biogas production, with the potential of biogas production from estimated as 19.11 million m^3/year. This amount of biogas corresponds to 11.68 million m^3 of natural gas per year.

Bearing in mind that animal waste is a huge problem in environmental pollution especially in the pollution of water and soil, using this potential will improve the protection from infectious diseases transmitted from animals to humans and it will reduce water and soil pollution. In order to make use of the potential an economically and energetically profitable, it is necessary to improve the system of organized collection of animal

waste. Taking into account the interest expressed by the companies, improvements in waste management collection, as well as veterinary sanitary measures in the EU accession process, it is reasonable to expect to achieve 50–70% of the potential biogas production from slaughterhouse waste by 2030. Of course, there is a condition that companies would decide to install high efficiency plants for biogas production and use it for heat and electricity production in their processes.

According to Table 5, total potential of biogas production in milk processing industry in Serbia was determined as 6.2 million m^3/year or 3.21 ktoe/year. Obtained results are comparable to the results of Coskun et al. [32], where total potential of biogas in milk processing industry in Turkey was estimated as 54.2 million m^3/year which represents 60% of the total milk production conducted in factories (in Serbia it is 50%).

Based on the results obtained by using biogas from wastewater generated in the dairy industry, annually 3.8 million m^3 of natural gas could be replaced. In addition, the fact that the dairy industry requires a cooling of certain types of dairy products, allows application of three-generation systems. Optimized CHP systems could be used simultaneously for cooling dairy products and to achieve a higher efficiency of biogas utilization. Also, the companies will have to fulfill very strict emission limit values for wastewaters and it is realistic to expect, in line with EU standards, that companies will build adequate wastewater treatment plants. Estimation is that 60–80% of the biogas production potential from milk industry can be realized by 2030, assuming that most of the companies opt for anaerobic digestion in their high efficiency wastewater treatment plants, especially in trigeneration systems.

It should be noted that in this paper different assumptions from other studies were incorporated in the calculations of the biogas production potentials in the Republic of Serbia. Such a method always involves a degree of uncertainty. For that reason the values of the parameters used in this study were always conservative ones.

Further, the uncertainties in all of the applied equations could arise from the amount of biogas yield from different feedstock used for the calculations. The biogas yield depends on the technology for biogas production used as well as from the process parameters employed.

The number of livestock in Serbia is declining in the past 5 years (Table 1) due to the unfavorable economic situation for its production. Therefore, the uncertainty of the calculation of the biogas production potential from livestock residues could arise from the uncertainty of the estimated number of livestock, as the year 2011 was used for the calculations. The future number of livestock in Serbia strongly depends on the economic measures that will be introduced by the government in order to improve the climate for agricultural production. The total slaughterhouse waste as well as the amount of processed milk used for the calculation of the biogas production potential is dependent on the same economic measures.

Also, the parameters: B – yield of corn silage dry matter per ha, A_2 – estimated fresh manure per head and B_2 – estimated percentage of dry matter, depend on farming practices in the country, which could change in the future.

The aim of this study was to establish a production potential for biogas in the Republic of Serbia. But, it should be considered also that import and/or export of raw materials could take place. Furthermore, the production potentials calculated in this study should be seen as the maximum possible production, which is not likely to be completely realized. The largest uncertainties are therefore not the actual production potentials but the possibility of realizing the estimated potentials in the future.

Theoretical potentials for biogas production described in this paper are limited by physical restrictions and represent the maximum theoretical value of the biogas production of the considered resources. Progress and technology transfer of biogas production, incentives and other economic instruments, better efficiency and management, can lead to increased utilization of the real potential of biogas.

4. Administrative framework for biogas energy

Serbia started to arrange legislation for renewable energy in 2004 with Energy Law [33], that introduced a status of privileged producers. According to this law, the producers who use RES for energy production got different subventions, tax benefits and, subsequently, a priority status on the energy market against other producers. In the period from 2011 to 2013 the law was revised in line with the EU standards. According to the presented obligations of the Republic of Serbia to EU [34] the new Energy Law [35] and related secondary legislation aimed to support the renewable energy sources [36,37] were adopted. This legislation initiated the process of reform of the energy sector in Serbia. The main objectives of this reform have been harmonization with EU regulation and formation and promotion of the free market principles. According to the new legislation, the animal by-products are considered as a source of biomass. This fact made producers using the animal by-products privileged (they also can get feed-in tariff). New legislation has required the government to develop and adopt a National Action Plan for Renewable Energy which sets targets for renewable energy for at least 10 years. Further, the Energy law introduced guarantees of origin for electricity and heat produced from renewable energy sources what enables producers to export “green energy”. Guarantees will be issued in units of one MWh.

The main institutions for the preparation of legislation and implementation of activities in biogas energy sector are

- The Ministry of Energy, Development and Environment Protection which is responsible for establishing legal framework, approving tariff systems, approving licensing systems, assuring the security of supply of energy sector. Ministry is also responsible for environment protection through environment impact assessments, climate change and waste management policy.
- The Ministry of Natural Resources, Mining and Spatial Planning which is responsible for sustainable utilization of natural resources, goods and spatial planning for biogas project.
- The Ministry of Construction and Urbanism which is in charge for obtaining building permits and urban planning for biogas plant.
- The Ministry of Agriculture, Forestry and Water Management which is responsible for production of biomass.
- The Ministry of Education, Science and Technological Development which is in charge for promoting, introduction of innovative biogas technology into the business sector.
- The Energy Agency of the Republic of Serbia (AERS) which is regulatory body for promoting and directing energy market development based on the principles of non-discrimination and effective competition, monitoring the implementation of regulations and energy systems operation codes, adjusting the

Table 6
Feed in tariffs for biogas power plant [38].

Biogas power plant capacity (MW)	Electricity price (cEuro/kWh)
Up to 0.2	15.66
From 0.2 to 1	$16.498-4.188 \cdot P$ [a]
Over 1	12.31
From animal by-product	12.31

[a] *P*-installed capacity in MW.

activities of energy entities in ensuring. The agency issues licenses, secondary legislation and establishes tariffs in regulated areas.
– "Electric Power Industry of Serbia" (EPS) which is the public enterprise for production and distribution of electricity.
– "Serbian Transmission System" (EMS) which is the public enterprise for electric energy transmission and market operator.
– "Srbijagas" is the public enterprise for natural gas distribution.

4.1. Incentives for biogas energy

Serbia introduced a new system of supporting measures for biogas project through the secondary legislative documents [36,37] in 2013. These documents prescribe conditions for granting the feed-in tariff (Table 6) and the commercial and procedural provisions for processing electricity feed-in from renewable sources.

This set of documents

- defines the renewable sources and their installation size eligible for receiving the feed-in tariff;
- sets the feed-in tariff as a function of the aforementioned eligibility criteria;
- prescribes the feed-in tariff application process;
- specifies the feed-in tariff disbursement procedure based on a specific contract between the electricity producer and the public supplier.

Feed-in tariffs are from 2.5 to 3 times higher than the market price of electricity in Serbia, which is about 5 Euro cents/kWh. The feed-in tariff is granted to privileged power producers for the period of 12 years. Final consumers pay about 0.04 Euro cents/kWh on their bills for feed-in tariff in 2013. It could be predicted that feed-in tariff will increase due to inflation in the Euro zone starting from 2014.

In Serbia, municipalities are responsible to stimulate production of thermal energy from biogas but so far they have had no funds available due to problems in municipalities′ budgets. Other incentives for biogas projects from government side are projects′ grants, tax credits, accelerated depreciation of fixed assets and foreign investments incentives.

5. Current status of biogas energy in Serbia

According to the Energy Sector Development Strategy of the Republic of Serbia by 2015 [3], related to the biogas energy, the rehabilitation and renewal of the production of the six large-scale biogas operators at 6 existing (cattle and pigs) farms, none of which are presently being operated due to technical problems and bad maintenance is planned. This was not done before due to economic problems and the process of economic transition of these farms.

Current biogas plants in Serbia are presented in Table 7. The biogas plants in the Republic of Serbia can be divided into two groups:

– Biogas plants as part of the waste water treatment systems.
– Biogas plants built on large cattle farms.

The biogas plants which are part of the waste water treatment systems were built in the following companies:

– Biogas plant in Public enterprise "Vodovod i kanalizacija" in Subotica.
– Biogas plant in company "Alltech Fermin" in Senta.
– Biogas plant in company "Carlsberg Srbija" brewery in Celarevo.

Public enterprise "Vodovod i kanalizacija" in Subotica built biogas plant for anaerobic treatment of sludge after municipality wastewater treatment. The plant was commissioned in November 2008, with the total capacity of 500 kW. The total capacity is divided into two cogeneration units, 250 kW each. For obtaining 250 kW of electric power at the output of each of the units it is necessary to provide biogas flow of 131 Nm^3/h. Percent of methane in biogas varies between 55% and 70%. The digestate remaining after the anaerobic digestion is landfilled, due to the incomplete legal framework that defines the use of sludge in agriculture as a fertilizer.

Company "Alltech Fermin" in Senta, for yeast production, has the total capacity of 1.5 MW of biogas production, as a part of the wastewater treatment system. The wastewater treatment plant can process 2500 m^3 of wastewater per day. Biogas produced in the plant is used for energy production. The total plant capacity is divided into two cogeneration units, 750 kW each. Heat energy from the cogeneration system is used in anaerobic fermenters and biogas purifier, and a small amount for working premises heating. The investment for the plant was around 9.5 M € [31].

In the "Carlsberg Srbija" brewery in Celarevo, biogas is produced after wastewater treatment in the company. The biogas is consumed within the company for heat generation. Maximum daily capacity of wastewater treatment is 2500 m^3. The residue of the fermentation from the anaerobic digestion is treated in aerobic fermentors and landfilled. Biogas production oscillates depending on the beer production, and there is a tank capacity of 1000 m^3 for biogas storage. Biogas production reaches over 100 m^3/h. The biogas is used in the boiler adapted for burning the mixture of natural gas and biogas. In this way, the annual consumption of natural gas, which is used in beer production, has been reduced by 10–15%. The total investment was around 4.5 M€ [31].

In the biogas plants in waste water treatment systems, large quantities of digestate remain. The landfilling or further use of this digestate can have significant impact on the economic feasibility of the plants. Therefore, it is necessary to make the long-term assessment of the possibilities for using the digestate in agriculture as fertilizers, both from the legal and from the ecological point of view.

Table 7
Biogas plants in Serbia – according to companies official data.

Biogas Plant	Output electrical power [kWe]	Feedstock
Public enterprise "Vodovod i kanalizacija" in Subotica	500	Sludge from wastewater treatment plant
"Alltech Fermin" in Senta	1500	Wastewater
Brewery of "Carlsberg Srbija" in Celarevo	Heat production	Wastewater
Lazar dairy farm in Blace	1000	Cow manure, silage and organic waste
Mirotin-Energo in Vrbas	1000	Cow manure, silage and organic waste
"Global Seed" in Curug	600	Cow manure, silage

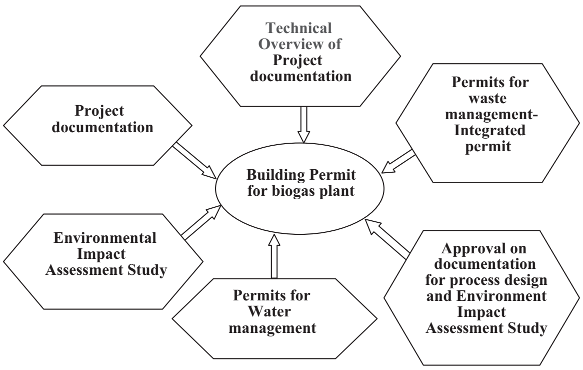

Fig. 4. Procedures for obtaining building permits for biogas project in the Republic of Serbia.

Fig. 5. Biogas plant in Mirotin-Energo company –Vrbas.

The biogas plants which are built on the large farms are

– Biogas plant in "Lazar dairy farm" in Blace.
– Biogas plant in Mirotin-Energo Company –Vrbas.
– Biogas plant Company "Global Seed" in Curug.

In May 2012, the "Lazar dairy farm" in Blace launched a biogas plant. This company has invested $ 2.6 million in the purchase and installation of the biogas technology. That technology solved the company's issues relating to the biodegradable waste from the farm and the dairy production line, using it for biogas and electricity generation. This technology transfer was conducted through the U.S. Department of Agriculture (USDA), aimed at promoting the use of renewable energy sources in the Serbian agriculture. The program was implemented by the U.S. Agency for International Development (USAID). The capacity of the biogas plant is 1 MW. For biogas production the company uses as a substrate cow livestock manure, whey and silage. This dairy plant represents the largest producer and supplier of milk in southern Serbia.

Biogas plant in Vrbas was built by Mirotin-Energo Company in 2012 (Fig. 5), with the total capacity of the plant of 1 MW. This plant produces power from the cattle manure and silage. Annual amount of substrate required for the operation of the plant is 22,000 t of solid manure, 4000 t of liquid manure and 10,000 t of silage. The maximum percent of methane in biogas is 55%. The company uses 8% of the produced heat from the cogeneration plant for heating of fermenters, while in winter months 200 kW of heat energy is used for heating of company's premises. Residual digestate from the anaerobic digestion is separated mechanically on solid and liquid fraction which is further used in agriculture as fertilizer. The investment was over 5 million Euros. The company plans to expand its capacity in the following period to 1.5 MW. Obtained heat from the new cogeneration system will be used for heating greenhouses in the winter months and drying of lucerne in the summer.

Company "Global Seed" built the biogas plant on its farm in Curug in February 2013. Installed capacity of the facility is 0.6 MW. By-product is 5000 t of quality organic compost per year that is used on agricultural land. In a biogas plant, electrical and heat energy are produced using liquid and solid manure obtained from cattle and from corn silage in organic production. For the biogas production they use annually 18,000 t of liquid manure, 9000 t of solid manure and 5000 t of silage. The plan is to expand the capacity to 1.2 MW by the end of 2013.

The common feature of all the biogas plants built on farms in Serbia is the usage of the corn silage as the co-substrate for biogas production. This can have a significant effect on the economic feasibility of the biogas plants, as the price of corn silage varies largely in Serbia due to different market and economic reasons.

According to the already present biogas plants, Serbian biogas plants usually use gas engines for production of electricity from biogas. On the other hand different power technologies can produce electricity from biogas: gas engines, gas turbines [38], Stirling engines [39], Organic Rankin cycle (ORC) [40], fuel cells [41], etc. This shows that the production of electricity from biogas is in initial phase in Serbia. Also, Serbia does not provide a technological bonus for companies which apply modern power technologies. Bearing in mind, that this is very effectively implemented in Germany, some pilot projects in this regard should be introduced in Serbia to demonstrate advantages of these technologies to farmers and industrial sectors. The Government needs to introduce a stimulating legal framework and government subsidies for the further diversification of applied technologies. Also, further promotion of these technologies should be done for universities, industries and farmers.

In February 2012, the Serbian Biogas Association was founded in order to coordinate the activities of all stakeholders in this field in the Republic of Serbia. By linking the business and academic institutions, farmers and civil society associations, aim is to develop and promote all aspects of the implementation of biogas in Serbia.

In the process of joining the EU, the Republic of Serbia will need to expand the use of the renewable energy sources, including biogas production. It can be expected that the biogas production potentials will first be used on large and medium-sized farms, industry and in the communal waste treatment systems. It is estimated that most of the plants will use biogas in the cogeneration units. The problem could be the effective heat energy usage, especially in the summer months. Therefore further work is needed in the field of efficient utilization of the heat energy produced from co-generation units in the drying technologies, greenhouses and similar usages.

6. Barriers for biogas technology in Serbia

Barriers for wider use of biogas in Serbia are classified into several groups:

- Transition in economy.
- Lack of competitive credit lines.
- Procedures for construction.
- Miscellaneous (lack of public awareness, lack of standards, etc.).

6.1. Transition in economy

The economy of Serbia faced many challenges in the last 10 years related to the structural transformation and economic crisis. Many challenges have characterized the previous period and the most important were privatization problems, the effects of the global economic crisis and budget deficits.

6.2. Lack of competitive credit lines

Use of biogas for energy production includes investments in different activities. The investment climate in Serbia is generally unpredictable, since in the current situation a long time period is necessary for the whole procedures for biogas project finishing. Also, an overall investment rating is very low. And local banks are unwilling to finance projects in Serbia. Moreover, there is a lack of capacity in the banks to analyze biogas projects. On the other hand, eminent banks such as EBRD, IFC, European Investment bank, and KfW are presented in Serbia and offer credit lines for biogas projects, directly or through local banks, but it is not sufficient in this moment.

6.3. Procedures for construction

The construction of biogas plants has to be in compliance with the Law on planning and construction [42]. The procedure is demanding and it covers the following stages: information on the location, location permit, preparation of the technical documentation (general design, preliminary design, detailed engineering, and contract, as built design) and technical supervision. Procedures for the obtaining building permits is shown in Fig. 4 ant it can be very long due to problems with the ownership, problems related for Environment Impact Assessment Study [43], the slowness of the administration, etc.

6.4. Lack of public awareness

Serbian farmers, agricultural and industrial sector are not familiar with production energy from biogas and do not understand the advantages of this technology. Many environmental organizations in Serbia do not believe that all biogas solutions are equally sustainable and available. The overall knowledge and skills about biogas production is low. There are no many established consulting companies and associations to educate the public about biogas technology.

6.5. Lack of standards

The variety of designs and standards in equipment design create problems with the equipment maintenance, specially bearing in mind that manufacturers generally does not provide service center based in Serbia, and many pieces of equipment in a biogas plant need a regular maintenance (works on engine, pumps, valves, cylinders, calibration, etc.). Usually, simple tasks can be performed locally by skilled technicians, but many other tasks may be done only by central services what drastically increases the costs of maintenance and, consequently, the total costs of biogas plants.

Biogas project is a complex mechanism which covers different groups of stakeholders: feedstock suppliers (farmers, food processing industries, companies), banks, investors, vendors of biogas equipment, authorities and developing agencies together with general public that might be affected by biogas plant. The development of biogas energy requires long-term incentive mechanism and diversification of biogas in all sectors (electricity, heat, natural gas network, transport) and promotion of this technology. Development of biogas project greatly depends on the feedstock availability, communication and joint actions between all stakeholders in that process.

7. Conclusion

The main resources that could be used for biogas production in the Republic of Serbia are agricultural crops directly provided for energy, livestock residues, municipal solid waste, slaughterhouse waste and wastewater from milk processing industry. The presented capacity and potentials analysis of biogas energy in Serbia in this work shows

- potential of biogas production from agricultural crops directly provided for energy in Serbia is 0.85 Mtoe;
- potential of biogas production from livestock residues in Serbia is 94.13 ktoe;
- potential of biogas production from MSW in Serbia is 49.72 ktoe;
- potential of biogas production from slaughterhouse waste in Serbia is 9.94 ktoe;
- potential of biogas production from milk processing industry in Serbia is 3.21 ktoe.

Theoretical potentials for biogas production described in this paper are limited by many factors related to the crops yield, land use, agricultural and industrial practices, current technologies, waste management, etc. and represent the maximum theoretical value of the biogas production from the resources considered. The economic valorization of the potentials for biogas production which can be utilized in the Republic of Serbia is highly dependent on economic situation in the country and policy of incentives. The deployment of biogas energy in Serbia needs long-term legal and economical incentives, transfer of biogas energy in all energy sectors (power, heat production and traffic), as well as introduction of advanced technologies and further promotion. The analysis of incentives, barriers and status of biogas technologies presented in this paper represent a contribution for the further improvement of the biogas sector in the Republic of Serbia.

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